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RESEARCH MEMORANDUM

CALCULATIONS OF THE DYNAMIC LATERAL STABILITY CHARACTERISTICS OF THE DOUGLAS D-558-II AIRPLANE IN HIGH-SPEED FLIGHT FOR VARIOUS WING LOADINGS AND ALTITUDES

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

An investigation has been made of the dynamic lateral stability characteristics of the Douglas D-558-II airplane at high speeds by means of calculations of the period and rate of damping of the lateral oscillation. The aerodynamic derivatives used in calculations applicable to subsonic speeds were obtained by applying theoretical compressibility corrections to values measured on a 0.13-scale model of the Douglas D-558-II in the Langley stability tunnel. The derivatives used for the supersonic speed range were estimated by theoretical procedures. The results indicate that the lateral oscillation of the airplane is expected to be poorly damped within the Mach number range from 0.6 to 1.0. Within this range, approximately neutral damping is indicated for the basic condition of the airplane for a wing loading of 60 pounds per square foot and altitudes of 40,000 and 50,000 feet. Improved damping characteristics are indicated at Mach numbers above 1.0; however, the present Bureau of Aeronautics criterion may not be satisfied for any of the conditions investigated.

The damping of the lateral oscillation was found to be critically dependent on the inclination of the principal axes. Rotation of the axes by 2° (downward at the nose of the airplane) from the inclination assumed for the basic condition resulted in an indication of dynamic instability for some flight conditions within the Mach number range from 0.6 to 1.0.

For the assumed variation of the moments of inertia and inclination of the principal axes with wing loading, the lateral oscillation became more highly damped as the wing loading increased.

The results of the calculations showed a rapid decrease in the period of the lateral oscillation with increase in Mach number through the subsonic speed range and a slower decrease through the supersonic speed range.

INTRODUCTION

The dynamic lateral stability characteristics of the Douglas D-558-II airplane at subsonic speeds have been the object of several analytical and experimental investigations. One such analytical investigation (reference 1) indicated instability of the lateral oscillation for certain airplane configurations. These results were in fair agreement with data obtained from preliminary flight tests of the airplane (reference 2). The present investigation is concerned with the extension of the calculations of the dynamic lateral stability to Mach numbers, altitudes, and wing loadings beyond the scope of reference 1. It is to be expected that the calculated dynamic lateral stability characteristics of the airplane at transonic and supersonic speeds cannot give an accurate quantitative measure of the stability of the actual airplane because of the uncertainties which exist in estimating the aerodynamic derivatives in these speed ranges. The results should, however, give a qualitative indication of the effects of various parameters on the airplane lateral stability characteristics for the conditions investigated. The calculations were made for the airplane configuration incorporating the vertical tail with its extended tip (fig. 1). All the subsonic aerodynamic derivatives used in the present investigation were based on low-speed subsonic derivatives measured in the 6-foot-diameter rolling-flow test section and the 6- by 6-foot curved-flow test section of the Langley stability tunnel. The supersonic derivatives were obtained from available theory.

SYMBOLS AND COEFFICIENTS

The symbols and coefficients used herein are defined as follows:

b wing span, feet

H altitude, feet

I_{X_O} moment of inertia about principal longitudinal axis, slug-feet^2

I_{Z_O} moment of inertia about principal normal axis, slug-feet^2

k_{X_O} radius of gyration about principal longitudinal axis, feet

k_{Z_O} radius of gyration about principal normal axis, feet

M	Mach number $\left(\dfrac{V}{\text{Local speed of sound}}\right)$
P	period of lateral oscillation, seconds
p	rolling angular velocity, radians per second
q	dynamic pressure $\left(\frac{1}{2}\rho V^2\right)$
r	yawing angular velocity, radians per second
S	wing area, square feet
$T_{1/2}$	time required for oscillation to reduce to half amplitude, seconds
T_2	time required for lateral oscillation to double amplitude, seconds
V	airplane velocity, feet per second
W	weight of airplane, pounds
α	angle of attack of airplane reference axis (fig. 2), degrees
β	angle of sideslip, radians
ϵ	angle between fuselage center line (reference axis) and principal axis, positive when reference axis is above principal axis at nose of airplane (fig. 2), degrees
ϵ_o	basic assumed values of ϵ, degrees
η	inclination of principal longitudinal axis of airplane with respect to flight path, positive when principal axis is above flight path at nose (fig. 2), degrees
ρ	mass density of air, slugs per cubic foot
C_L	trim lift coefficient (W/qS)
C_Y	lateral-force coefficient $\left(\dfrac{\text{Lateral force}}{qS}\right)$

C_n yawing-moment coefficient $\left(\frac{\text{Yawing moment}}{qSb}\right)$

C_l rolling-moment coefficient $\left(\frac{\text{Rolling moment}}{qSb}\right)$

$$C_{L_\alpha} = \frac{\partial C_L}{\partial \alpha}$$

$$C_{Y_\beta} = \frac{\partial C_Y}{\partial \beta}$$

$$C_{n_\beta} = \frac{\partial C_n}{\partial \beta}$$

$$C_{l_\beta} = \frac{\partial C_l}{\partial \beta}$$

$$C_{Y_p} = \frac{\partial C_Y}{\partial \left(\frac{pb}{2V}\right)}$$

$$C_{l_p} = \frac{\partial C_l}{\partial \left(\frac{pb}{2V}\right)}$$

$$C_{n_p} = \frac{\partial C_n}{\partial \left(\frac{pb}{2V}\right)}$$

$$C_{Y_r} = \frac{\partial C_Y}{\partial \left(\frac{rb}{2V}\right)}$$

$$C_{n_r} = \frac{\partial C_n}{\partial \left(\frac{rb}{2V}\right)}$$

$$C_{l_r} = \frac{\partial C_l}{\partial \left(\frac{rb}{2V}\right)}$$

SCOPE AND METHODS

The investigation reported herein includes the determination of the effects of Mach number, wing loading, and altitude on the dynamic lateral stability characteristics of the Douglas D-558-II research airplane in the clean condition (slats, flaps, and gear retracted). In addition, the effects of variation in principal-axes inclination by $\pm 2^{\circ}$ from base values also were investigated. This latter variation was studied because of the uncertainty which generally exists with regard to the principal-axes inclination. The ranges of the various parameters were as follows: Mach number from 0.5 to 1.7; wing loadings of 60, 76, and 92 pounds per square foot; and altitudes of 30,000 feet, 40,000 feet, and 50,000 feet.

All calculations were made for level flight by use of the lateral equations of motion as given in reference 3. The quantities calculated were the period and rate of damping of the lateral oscillation and the rate of damping of the aperiodic modes of motion (spiral and roll). Power effects were believed to be small for all the conditions investigated and hence were neglected.

MASS CHARACTERISTICS

The estimated mass characteristics of the airplane at various wing loadings were obtained from estimates made at the NACA High-Speed Flight Research Station, Edwards Air Force Base, Muroc, Calif. Examination of these characteristics indicated a systematic variation of the airplane moments of inertia and inclination of the principal axes with wing loading. Average curves were drawn through the given points, and values were taken from the average curves (fig. 2) for the specific wing loadings investigated.

AERODYNAMIC CHARACTERISTICS

Results of Low-Speed Wind-Tunnel Tests

The subsonic stability derivatives used in this investigation were based on values measured on a 0.13-scale model of the Douglas D-558-II airplane in the Langley stability tunnel at a Mach number of 0.16 and a Reynolds number of 1.1×10^{6}. These data are shown in figures 3 and 4. The wind-tunnel investigation also included the determination of the static lateral-stability derivatives of the model with the vertical tail off (fig. 4(a)). The measured data for the Douglas D-558-II model show the usual departure of the derivatives from their initial trends at

moderately low angles of attack - a phenomenon generally associated with low Reynolds number tests. Since the airplane flight Reynolds number is considerably higher than the test Reynolds number, the low angle-of-attack trends of the data were extended to higher angles of attack. It is believed that the curves thus obtained may represent the airplane characteristics more closely at high angles of attack than do the measured characteristics.

Estimated Mach Number Effects

Compressibility corrections were applied only to the increments of the aerodynamic derivatives contributed by the wing and vertical tail. The wing and vertical-tail contributions to the lateral-stability derivatives (at low speeds) were separated by use of the data of figure 4 and equations (similar to those of reference 4 but with rolling parameters corrected for sidewash as indicated by reference 5) for the vertical-tail contribution to the derivatives. Compressibility corrections were applied in the subsonic speed range (up to $M = 0.9$) as indicated by the charts of reference 6. The variation of the airplane lift-curve slope with Mach number is shown in figure 5. The subsonic values of the lift-curve slope and a value at $M = 1.2$ were obtained from reference 7. The curve in the supersonic speed range was estimated by use of the methods of references 8 and 9. The variation of the vertical-tail lift-curve slope with Mach number is also shown in figure 5. The value at $M = 0$ was estimated from the C_{Y_β} values of figure 4(a). The calculated value of C_{L_α} of the vertical tail and the geometric sweep angle then were used in conjunction with reference 10 to determine an effective vertical-tail aspect ratio. The effective aspect ratio (approx. 1.4) and geometric sweep angle were used with references 6 and 8 to determine the variation of the tail C_{L_α} with Mach number throughout the Mach-number range investigated. The theoretical values in the transonic and supersonic speed ranges were then reduced to bring them in closer agreement with available data on low-aspect-ratio wings.

The wing contributions to the various derivatives at supersonic speeds were estimated with the aid of references 8, 9, 11, 12, and 13. The vertical-tail contribution to the derivatives was estimated by use of figure 5 and equations similar to those of reference 4 with a sidewash correction applied to the rolling derivatives as indicated by reference 5. The lack of experimental supersonic data for the aerodynamic derivatives of models similar to the Douglas D-558-II airplane has made verification of the calculated derivatives impossible; however, the derivatives were estimated by the best procedures available and show a reasonable variation with Mach number (fig. 6)

Two sets of derivatives were available for any particular flight condition at moderate and high angles of attack; one set was based on the measured low-speed derivatives (referred to as "basic data"), and the other set was based on the curves obtained by extending the low-speed data so that the low angle-of-attack trends of the data were maintained at high angles of attack. Corresponding sets of calculations of the period and rate of damping were made for conditions where the two sets of derivatives differed measurably.

All the aerodynamic and mass characteristics for the condition $\epsilon = \epsilon_o$ are presented in table I. The characteristics are exactly the same for the conditions $\epsilon = \epsilon_o - 2^o$ and $\epsilon = \epsilon_o + 2^o$ with the exception of the values of ϵ and η. The values of η corresponding to any value of ϵ can be found from the relation $\eta = \alpha - \epsilon$.

CALCULATED DYNAMIC LATERAL STABILITY CHARACTERISTICS

The calculated period and rate of damping of the lateral oscillation for each condition investigated are given in table II. No results are presented for the aperiodic modes of motion since these modes were stable in all but a very few cases, and in those conditions the rate of divergence was very low.

The variations of the period and rate of damping of the lateral oscillation with Mach number are shown in figures 7, 8, and 9 for several wing loadings, altitudes, and inclinations of the principal axes. All curves of these figures show approximately the same general variations with Mach number. Quantitatively, however, the variations of the period and rate of damping with Mach number and the effects of wing loading and altitude depend to a large extent on the assumed inclination of the principal axes.

Variation of Period and Damping with Mach Number

The results of this investigation (figs. 7, 8, and 9) show a maximum period of about three seconds at low Mach numbers and a decrease in period with increase in Mach number. The rate of decrease of the period is quite rapid in the subsonic and transonic speed ranges but somewhat less rapid at supersonic speeds. The shortest period calculated was about 1.5 seconds and was generally obtained at Mach numbers above 1.1 for all conditions investigated. Variations of wing loading, altitude, or principal-axes inclination had no appreciable effect on the variation of the period with Mach number. In general, the trends of the variation of the rate of damping of the lateral oscillation $(T_{1/2}$ or $T_2)$ with Mach number were the same for all wing loadings, altitudes, and principal-axes

inclinations investigated. The results show a fair degree of stability (small $T_{1/2}$) at the lowest and the highest Mach numbers. The degree of stability at intermediate Mach numbers depended somewhat on the wing loading, altitude, and assumed inclination of the principal axes, and less stability was generally indicated at these Mach numbers than at the highest or lowest Mach numbers. The results of the calculation near Mach number 1.0 are questionable because of the uncertainty which generally exists with regard to estimated aerodynamic derivatives in this speed range.

Effect of Wing Loading

An increase in wing loading caused an appreciable increase in the rate of damping of the lateral oscillations for all subsonic conditions investigated but had very little effect at supersonic speeds. It should be noted that in this investigation the mass characteristics used were such that the radii of gyration and the principal-axes inclination of the airplane varied simultaneously with wing loading; therefore, the effect of wing loading is not comparable to the effect previously reported (reference 1) in which the radii of gyration and the inclination of the principal axes were assumed to be independent of wing loading

Effect of Altitude

An increase in altitude caused a decrease in stability throughout the Mach number range for all wing loadings and principal-axes inclinations considered. The decrease in stability appeared to be of little importance for the heavier wing loadings (76 and 92 pounds per square foot), generally amounting to about only 1 or 2 seconds in $T_{1/2}$. At a wing loading of 60, however, the effect of altitude was a little more pronounced.

Effect of Principal-Axes Inclination

The results of this investigation indicate that the inclination of the principal axes is a primary factor in determining the stability characteristics of the Douglas D-558-II airplane. With the most favorable inclination assumed $\left(\epsilon = \epsilon_o - 2^\circ\right)$, the calculations indicated a fair degree of stability for the wing loadings and altitudes considered; whereas, for the most unfavorable inclination $\left(\epsilon = \epsilon_o + 2^\circ\right)$, the airplane generally was marginally stable at subsonic speeds and either marginally stable or actually unstable at transonic speeds.

Effect of Using Data from Extended Curves

It was mentioned in the section entitled "Aerodynamic Characteristics" that the trends of the measured derivatives of the Douglas D-558-II model at low angles of attack were extended to high angles of attack in an attempt to make the data (obtained at low Reynolds number) more applicable to the greater flight Reynolds numbers of the full-scale airplane. At moderate and high angles of attack, it was possible to obtain two sets of derivatives; one set based on the measured data (referred to as "basic data") and the other set based on the extended curves. Corresponding sets of calculations were made for all conditions in which the measured data and extended curves differed measurably. The data of figures 7, 8, and 9 show that the use of extended derivatives gave approximately the same period and rate of damping of the lateral oscillation as did the use of the basic derivatives. In general, the use of values from the extended curves decreased slightly the rate of damping of the oscillation.

Effect of Neglecting the Parameters C_{Y_p} and/or C_{Y_r}

In making dynamic lateral-stability calculations it has been common practice to neglect C_{Y_p} and C_{Y_r} because several investigations have indicated only a small effect of these parameters on P and $T_{1/2}$ and because of the amount of labor saved by neglecting them. The present computations were made on an automatic digital computer; therefore, only a small saving in time and work would have been made by neglecting C_{Y_p} and C_{Y_r}. Because both C_{Y_p} and C_{Y_r} were quite large for several of the conditions investigated, this investigation appeared to offer a good opportunity to evaluate the effects of large values of these parameters on P and $T_{1/2}$, at least for one particular configuration. The results of the calculations are presented for one case only, and that case (one of marginal stability) is specified by the following parameters: $M = 0.7$, $\frac{W}{S} = 60$, $H = 40,000$ feet, $\epsilon = \epsilon_o$, $C_{Y_p} = 0.340$, $C_{Y_r} = 0.727$. The results are shown in the following table:

C_{Y_p}	C_{Y_r}	P (sec)	$T_{1/2}$ (sec)
0.340	0.727	2.76	13.69
0	.727	2.77	14.73
.340	0	2.76	13.98
0	0	2.76	14.13

The results indicate that neglecting C_{Y_p} and/or C_{Y_r} for this case had no substantial effect on the calculated period and rate of damping.

Comparison of the Calculated Period and Damping with the Bureau of Aeronautics Criterion for Satisfactory Period-Damping Relationship

The present Bureau of Aeronautics criterion for satisfactory characteristics of the lateral oscillation (Dutch roll) is contained in reference 14. The criterion is that the damping shall be positive and shall be such that the time required to damp to half amplitude and the period shall fall within the satisfactory area of charts such as those of figures 10, 11, and 12. The points on the charts were taken from figures 7, 8, and 9 and show that the Douglas D-558-II airplane does not meet the Bureau's criterion for a great majority of the conditions investigated.

CONCLUSIONS

Results of calculations of the dynamic lateral stability characteristics of the Douglas D-558-II airplane in high-speed flight indicate the following conclusions:

1. The lateral oscillation of the Douglas D-558-II is expected to be poorly damped within the Mach number range from 0.6 to 1.0. Within this range, approximately neutral damping is indicated for the assumed basic condition of the airplane for a wing loading of 60 pounds per square foot and altitudes of 40,000 and 50,000 feet. Improved damping characteristics are indicated at Mach numbers above 1.0; however, the present Bureau of Aeronautics criterion may not be satisfied for any of the conditions investigated.

2. The damping of the lateral oscillation was found to be critically affected by the inclination of the principal axes. Rotation of the principal axes by 2° (downward at the airplane nose) from the inclination assumed for the basic condition resulted in an indication of dynamic instability for some flight conditions within the Mach number range from 0.6 to 1.0.

3. For the assumed variation of the moments of inertia and inclination of principal axes with wing loading, the lateral oscillation became more highly damped as the wing loading increased.

4. The calculations showed a rapid decrease in the period of the lateral oscillation with increase in Mach number through the subsonic speed range and a slower decrease through the supersonic speed range for all conditions investigated.

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TABLE I.- STABILITY DERIVATIVES AND MASS CHARACTERISTICS

OF THE DOUGLAS D-558-II AIRPLANE

$\epsilon = \epsilon_o$

M	W/S	H	α	ϵ	η	C_L	C_{Y_β}	C_{n_β}	C_{l_β}	C_{Y_p}	C_{n_p}	C_{l_p}	C_{Y_r}	C_{n_r}	C_{l_r}	k_{X_o}/b	k_{Z_o}/b
0.5	60	30,000	6.35	3.70	2.65	0.548	-0.810	0.199	-0.140	0.316	-0.010	-0.316	0.673	-0.585	0.144	0.1244	0.3707
.5	60	30,000	6.35	3.70	2.65	.548	[a]-.825	.199	[a]-.155	[a].490	[a]-.078	-.316	[a].696	[a]-.569	[a].174	.1244	.3707
.5	76	30,000	8.55	1.66	6.89	.695	-.789	.205	-.108	.342	-.029	-.230	.635	-.580	.117	.1113	.3620
.5	76	30,000	8.55	1.66	6.89	.695	[a]-.835	.205	[a]-.172	[a].581	[a]-.098	[a]-.358	[a].690	[a]-.560	[a].190	.1113	.3620
.6	60	30,000	3.86	3.70	.16	.382	-.830	.200	-.134	.341	-.050	-.303	.698	-.578	.161	.1244	.3707
.6	76	30,000	5.30	1.66	3.64	.484	-.830	.202	-.140	.336	-.035	-.314	.690	-.581	.160	.1113	.3620
.7	60	30,000	2.35	3.70	-1.35	.279	-.835	.201	-.126	.322	-.033	-.301	.720	-.599	.157	.1244	.3707
.7	76	30,000	3.35	1.66	1.69	.354	-.841	.205	-.132	.352	-.046	-.309	.727	-.594	.166	.1113	.3620
.7	92	30,000	4.28	0	4.28	.428	-.847	.209	-.137	.345	-.048	-.315	.728	-.593	.170	.1027	.3460
.7	92	30,000	4.28	0	4.28	.428	-.847	.209	[a]-.143	[a].405	[a]-.052	-.315	.728	-.593	[a].176	.1027	.3460
.7	60	40,000	4.45	3.70	.75	.448	-.847	.210	-.138	.340	-.044	-.317	.727	-.593	.170	.1244	.3707
.7	60	40,000	4.45	3.70	.75	.448	-.847	.210	[a]-.145	[a].415	[a]-.056	-.317	.727	-.593	[a].180	.1244	.3707
.7	76	40,000	6.10	1.66	4.44	.567	-.833	.211	-.148	.328	-.012	-.330	.711	-.605	.160	.1113	.3620
.7	76	40,000	6.10	1.66	4.44	.567	[a]-.846	.211	[a]-.160	[a].490	[a]-.073	-.330	[a].720	[a]-.585	[a].195	.1113	.3620
.7	92	40,000	7.65	0	7.65	.686	-.810	.214	-.133	.341	-.017	-.280	.662	-.600	.144	.1027	.3460
.7	92	40,000	7.65	0	7.65	.686	[a]-.852	.214	[a]-.174	[a].565	[a]-.090	[a]-.358	[a].720	[a]-.578	[a].210	.1027	.3460
.7	60	50,000	8.10	3.70	4.40	.719	-.802	.215	-.124	.350	-.025	-.259	.655	-.599	.135	.1244	.3707
.7	60	50,000	8.10	3.70	4.40	.719	[a]-.855	.215	[a]-.178	[a].585	[a]-.095	[a]-.368	[a].720	[a]-.576	[a].215	.1244	.3707
.8	60	30,000	1.30	3.70	-2.40	.214	-.850	.210	-.124	.290	-.018	-.313	.736	-.618	.160	.1244	.3707
.8	76	30,000	2.00	1.66	.34	.272	-.852	.211	-.136	.326	-.030	-.315	.740	-.613	.170	.1113	.3620
.8	92	30,000	2.65	0	2.65	.329	-.856	.213	-.135	.350	-.040	-.317	.740	-.610	.177	.1027	.3460
.8	60	40,000	2.85	3.70	-.85	.343	-.859	.214	-.137	.358	-.042	-.319	.740	-.609	.179	.1244	.3707
.8	76	40,000	3.90	1.66	2.24	.434	-.861	.220	-.143	.380	-.050	-.325	.739	-.604	.190	.1113	.3620
.8	60	50,000	5.30	3.70	1.60	.552	-.867	.225	-.150	.372	-.040	-.337	.734	-.608	.190	.1244	.3707
.9	60	30,000	.47	3.70	-3.23	.169	-.875	.230	-.122	.255	-.002	-.326	.750	-.640	.168	.1244	.3707
.9	76	30,000	.98	1.66	-.68	.215	-.875	.226	-.130	.289	-.013	-.326	.758	-.638	.176	.1113	.3620
.9	92	30,000	1.48	0	1.48	.262	-.875	.225	-.136	.320	-.023	-.330	.763	.635	.185	.1027	.3460
.9	60	40,000	1.53	3.70	-2.17	.270	-.873	.225	-.138	.324	-.025	-.330	.765	-.635	.186	.1244	.3707
.9	76	40,000	2.30	1.66	.64	.342	-.878	.226	-.145	.367	-.039	-.330	.771	-.631	.198	.1113	.3620
.9	92	40,000	3.05	0	3.05	.415	-.882	.231	-.149	.395	-.050	-.333	.779	-.627	.210	.1027	.3460
.9	60	50,000	3.25	3.70	-.45	.435	-.883	.231	-.151	.400	-.052	-.336	.780	-.626	.213	.1244	.3707
.9	76	50,000	4.50	1.66	2.84	.551	-.899	.235	-.158	.401	-.051	-.346	.780	-.624	.220	.1113	.3620
.9	76	50,000	4.50	1.66	2.84	.551	-.899	.235	[a]-.170	[a].468	[a]-.063	-.346	.780	-.624	[a].233	.1113	.3620
1.0	76	30,000	.55	1.66	-1.11	.174	-1.000	.300	-.136	.255	0	-.351	.900	-.728	.197	.1113	.3620
1.0	92	30,000	.90	0	.90	.210	-1.000	.300	-.141	.280	-.009	-.351	.910	-.726	.205	.1027	.3460
1.0	60	40,000	1.00	3.70	-2.70	.218	-1.000	.300	-.142	.286	-.010	-.351	.910	-.725	.206	.1244	.3707
1.0	76	40,000	1.60	1.66	-0.06	.277	-1.000	.300	-.149	.320	-.022	-.354	.921	-.724	.215	.1113	.3620
1.0	60	50,000	2.40	3.70	-1.30	.352	-1.005	.302	-.155	.351	-.034	-.355	.930	-.719	.229	.1244	.3707
1.0	76	50,000	3.35	1.66	1.69	.446	-1.011	.305	-.160	.377	-.045	-.361	.928	-.712	.247	.1113	.3620
1.1	60	30,000	.05	3.70	-3.65	.114	-1.037	.315	-.080	.143	-.028	-.385	.957	-.793	.204	.1244	.3707
1.1	76	30,000	.39	1.66	-1.27	.144	-1.031	.317	-.075	.166	-.038	-.380	.961	-.785	.193	.1113	.3620
1.1	92	30,000	.75	0	.75	.174	-1.031	.318	-.071	.186	-.046	-.372	.965	-.779	.185	.1027	.3460
1.1	60	40,000	.81	3.70	-2.89	.181	-1.031	.319	-.070	.192	-.048	-.371	.965	-.777	.183	.1244	.3707
1.1	76	40,000	1.36	1.66	-.30	.229	-1.031	.320	-.066	.225	-.059	-.365	.968	-.768	.171	.1113	.3620
1.1	60	50,000	2.10	3.70	-1.60	.292	-1.025	.321	-.061	.270	-.075	-.359	.970	-.756	.156	.1244	.3707
1.1	76	50,000	2.98	1.66	1.32	.370	-1.021	.319	-.054	.320	-.092	-.350	.967	-.746	.141	.1113	.3620
1.3	60	30,000	-.15	3.70	-3.85	.081	-.958	.270	-.073	.090	-.008	-.389	.860	-.740	.187	.1244	.3707
1.3	76	30,000	.15	1.66	-1.51	.102	-.956	.270	-.070	.103	-.010	-.381	.865	-.735	.180	.1113	.3620
1.3	60	40,000	.55	3.70	-3.15	.130	-.955	.271	-.065	.121	-.014	-.379	.869	-.727	.171	.1244	.3707
1.3	76	40,000	1.05	1.66	-.61	.164	-.952	.271	-.060	.143	-.018	-.371	.873	-.718	.162	.1113	.3620
1.3	60	50,000	1.65	3.70	-2.05	.208	-.952	.271	-.055	.170	-.023	-.369	.876	-.708	.150	.1244	.3707
1.3	76	50,000	2.48	1.66	.82	.264	-.952	.270	-.050	.202	-.030	-.362	.877	-.696	.136	.1113	.3620
1.5	60	40,000	.36	3.70	-3.34	.097	-.921	.245	-.065	.058	-.005	-.360	.820	-.702	.166	.1244	.3707
1.5	60	50,000	1.40	3.70	-2.30	.157	-.918	.247	-.055	.080	-.013	-.354	.828	-.683	.146	.1244	.3707
1.5	76	50,000	2.10	1.66	.44	.199	-.912	.248	-.050	.100	-.017	-.350	.830	-.672	.135	.1113	.3620
1.7	60	50,000	1.20	3.70	-2.50	.123	-.887	.216	-.053	.047	-.005	-.325	.808	-.675	.141	.1244	.3707

[a]Data used from extended curves.

TABLE II.- CALCULATED PERIOD AND DAMPING CHARACTERISTICS

OF THE DOUGLAS D-558-II AIRPLANE

Mach number, M	Wing loading, W/S (lb/sq ft)	Altitude, H (ft)	Lift coefficient, C_L	Lateral oscillation								
				$\epsilon = \epsilon_o - 2^o$			$\epsilon = \epsilon_o$			$\epsilon = \epsilon_o + 2^o$		
				P (sec)	$T_{1/2}$ (sec)	T_2 (sec)	P (sec)	$T_{1/2}$ (sec)	T_2 (sec)	P (sec)	$T_{1/2}$ (sec)	T_2 (sec)
0.5	60	30,000	0.548	2.83	3.04	---	3.02	4.89	------	3.20	12.87	------
.5	60	30,000	.548	[a]2.75	[a]4.06	---	[a]2.93	[a]8.60	------	[a]3.11	-------	[a]65.21
.5	76	30,000	.695	2.66	2.66	---	2.84	3.39	------	3.04	4.85	------
.5	76	30,000	.695	[a]2.44	[a]1.95	---	[a]2.62	[a]2.58	------	[a]2.82	[a]4.06	------
.6	60	30,000	.382	2.55	4.57	---	2.70	13.23	------	2.85	-------	16.39
.6	76	30,000	.484	2.41	2.14	---	2.60	3.19	------	2.79	6.74	------
.7	60	30,000	.279	2.31	4.49	---	2.44	15.51	------	2.55	-------	12.45
.7	76	30,000	.354	2.23	2.44	---	2.39	4.41	------	2.55	23.09	------
.7	92	30,000	.428	2.07	1.65	---	2.24	2.29	------	2.41	4.03	------
.7	92	30,000	.428	[a]2.05	[a]1.64	---	[a]2.22	[a]2.30	------	[a]2.40	[a]4.13	------
.7	60	40,000	.448	2.59	5.08	---	2.76	13.69	------	2.93	-------	19.04
.7	60	40,000	.448	[a]2.57	[a]5.51	---	[a]2.75	[a]19.68	------	[a]2.92	-------	[a]12.70
.7	76	40,000	.567	2.39	2.29	---	2.59	3.16	------	2.81	5.65	------
.7	76	40,000	.567	[a]2.34	[a]2.65	---	[a]2.53	[a]4.01	------	[a]2.74	[a]9.68	------
.7	92	40,000	.686	2.22	2.08	---	2.38	2.51	------	2.57	3.29	------
.7	92	40,000	.686	[a]2.09	[a]1.82	---	[a]2.25	[a]2.24	------	[a]2.45	[a]3.11	------
.7	60	50,000	.719	2.98	5.82	---	3.18	8.76	------	3.40	19.54	------
.7	60	50,000	.719	[a]2.80	[a]5.14	---	[a]3.01	[a]9.40	------	[a]3.25	[a]180.0	------
.8	60	30,000	.214	2.05	4.13	---	2.16	14.42	------	2.25	-------	11.97
.8	76	30,000	.272	2.04	2.44	---	2.18	5.24	------	2.32	-------	47.75
.8	92	30,000	.329	1.93	1.67	---	2.09	2.57	------	2.24	5.94	------
.8	60	40,000	.343	2.44	6.24	---	2.59	49.35	------	2.74	-------	8.74
.8	76	40,000	.434	2.31	3.00	---	2.50	5.44	------	2.69	40.48	------
.8	60	50,000	.552	2.76	6.04	---	2.96	14.69	------	3.17	-------	27.58
.9	60	30,000	.169	1.80	3.58	---	1.87	9.74	------	1.94	-------	20.80
.9	76	30,000	.215	1.85	2.36	---	1.96	5.30	------	2.07	-------	36.84
.9	92	30,000	.262	1.77	1.59	---	1.91	2.65	------	2.04	7.87	------
.9	60	40,000	.270	2.22	6.72	---	2.34	-----	135.9	2.46	-------	6.60
.9	76	40,000	.342	2.17	3.27	---	2.34	8.02	------	2.51	-------	16.84
.9	92	40,000	.415	2.02	2.15	---	2.19	3.33	------	2.38	8.65	------
.9	60	50,000	.435	2.61	9.84	---	2.80	-----	65.42	2.98	-------	7.46
.9	76	50,000	.551	2.45	3.80	---	2.66	6.75	------	2.88	57.33	------
.9	76	50,000	.551	[a]2.41	[a]3.89	---	[a]2.63	[a]7.34	------	[a]2.86	-------	[a]342.6
1.0	76	30,000	.174	1.48	1.86	---	1.56	3.34	------	1.62	11.14	------
1.0	92	30,000	.210	1.45	1.38	---	1.55	2.17	------	1.63	4.76	------
1.0	60	40,000	.218	1.77	4.02	---	1.85	9.69	------	1.92	-------	42.19
1.0	76	40,000	.277	1.79	2.66	---	1.90	5.14	------	1.78	2.58	------
1.0	60	50,000	.352	2.15	6.30	---	2.27	22.03	------	2.39	-------	15.82
1.0	76	50,000	.446	2.09	3.51	---	2.25	6.25	------	2.41	37.21	------
1.1	60	30,000	.114	1.25	1.78	---	1.27	2.14	------	1.28	2.43	------
1.1	76	30,000	.144	1.33	1.71	---	1.36	2.27	------	1.38	2.94	------
1.1	92	30,000	.174	1.34	1.47	---	1.39	1.98	------	1.42	2.70	------
1.1	60	40,000	.181	1.55	2.75	---	1.58	3.30	------	1.59	3.71	------
1.1	76	40,000	.229	1.64	2.59	---	1.69	3.43	------	1.72	4.47	------
1.1	60	50,000	.292	1.93	4.35	---	1.97	5.21	------	2.00	5.86	------
1.1	76	50,000	.370	2.03	3.96	---	2.10	5.15	------	2.16	6.63	------
1.3	60	30,000	.081	1.15	1.60	---	1.16	1.96	------	1.17	2.28	------
1.3	76	30,000	.102	1.23	1.51	---	1.26	2.04	------	1.28	2.75	------
1.3	60	40,000	.130	1.43	2.42	---	1.45	2.98	------	1.47	3.46	------
1.3	76	40,000	.164	1.52	2.18	---	1.56	2.96	------	1.59	3.96	------
1.3	60	50,000	.208	1.80	3.69	---	1.83	4.50	------	1.85	5.17	------
1.3	76	50,000	.264	1.90	3.25	---	1.96	4.28	------	2.01	5.63	------
1.5	60	40,000	.097	1.31	2.20	---	1.34	2.80	------	1.35	3.38	------
1.5	60	50,000	.157	1.64	3.31	---	1.67	4.13	------	1.69	4.88	------
1.5	76	50,000	.199	1.72	2.89	---	1.77	3.86	------	1.82	5.20	------
1.7	60	50,000	.123	1.55	2.98	---	1.59	3.76	------	1.61	4.54	------

[a]Values obtained when data from extended curves were used in the calculations.

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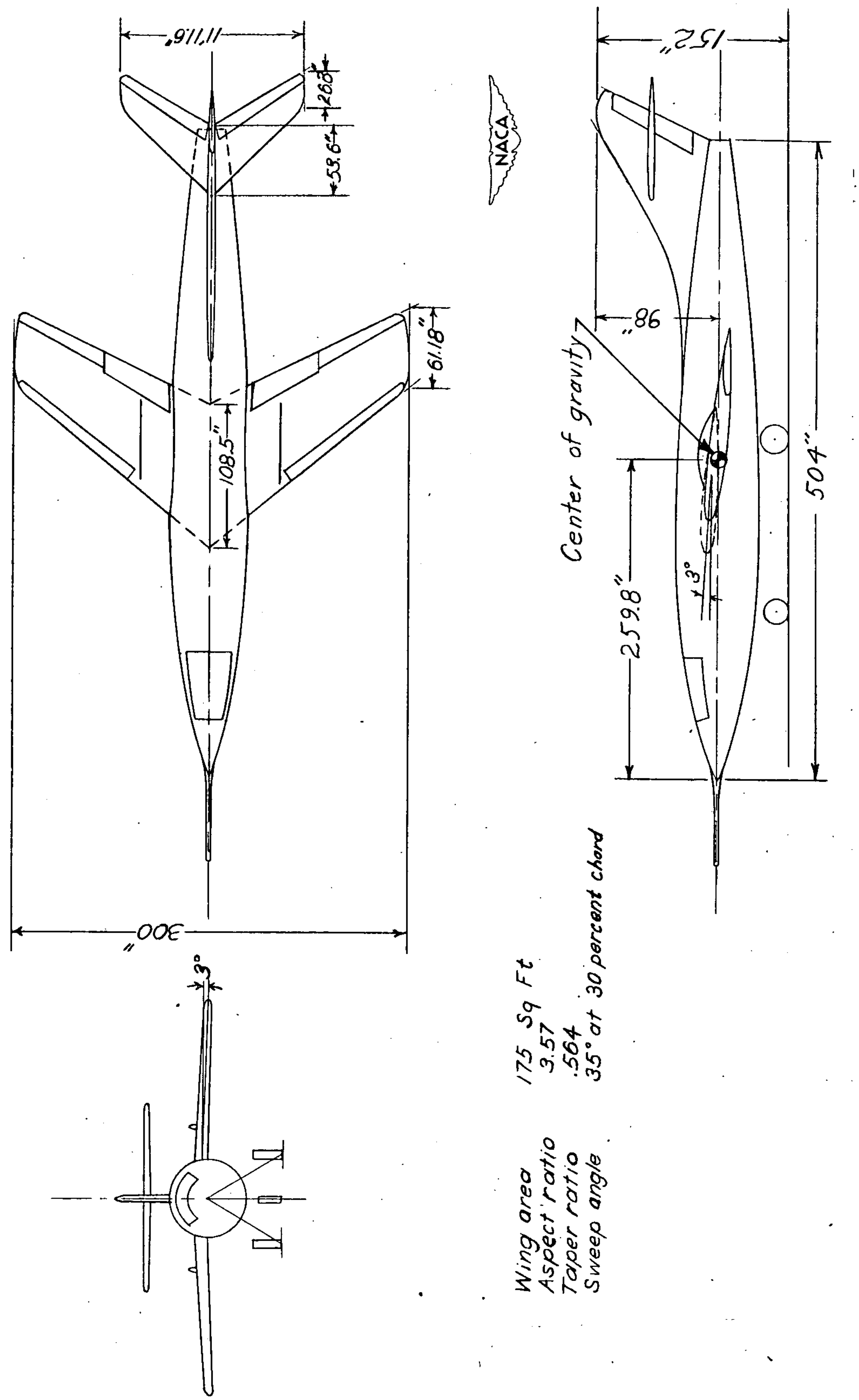


Figure 1.- Drawing of Douglas D-558-II high-speed research airplane.

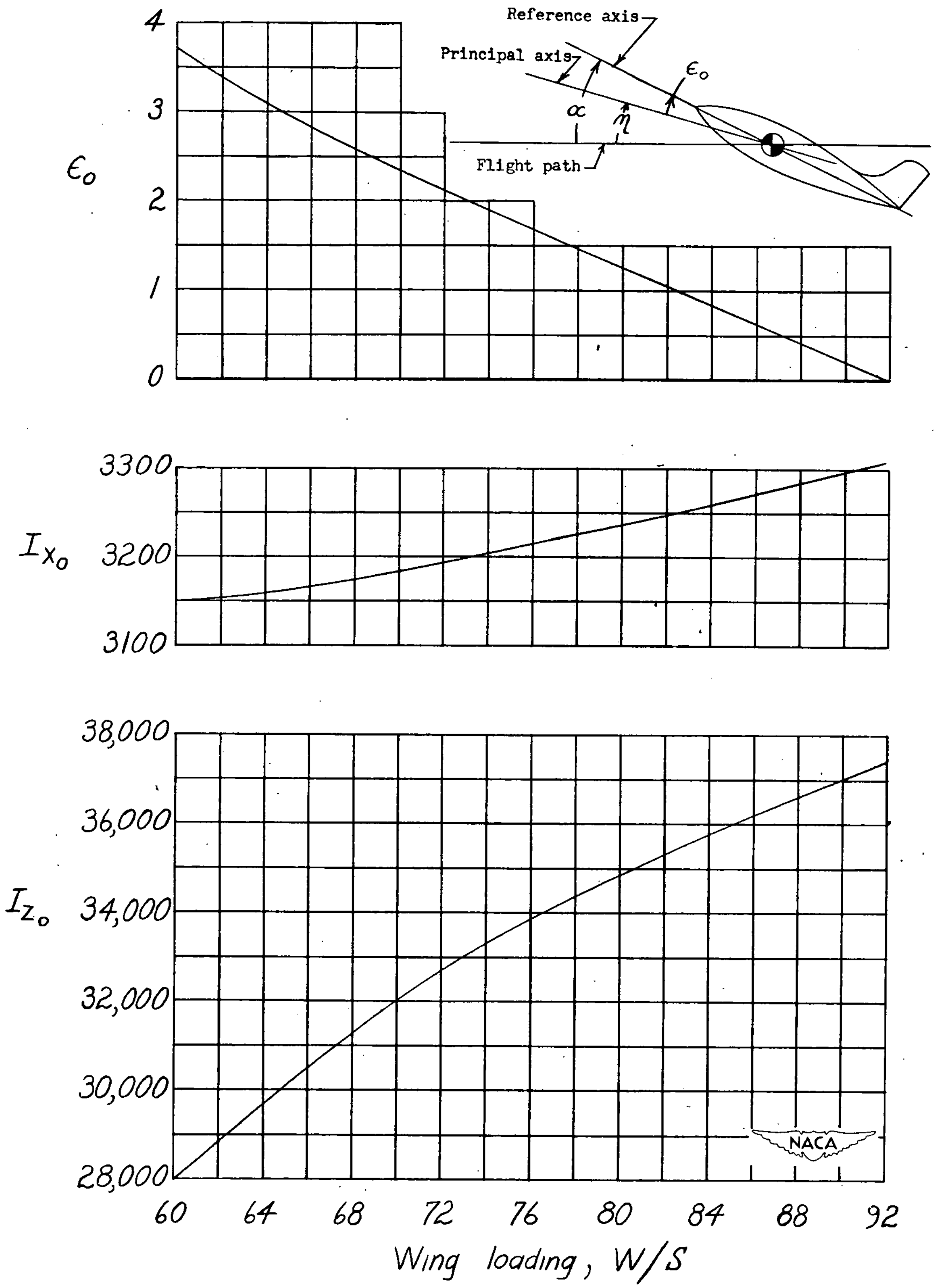


Figure 2.- Variation of moments of inertia about principal axes and inclination of principal axes with wing loading.

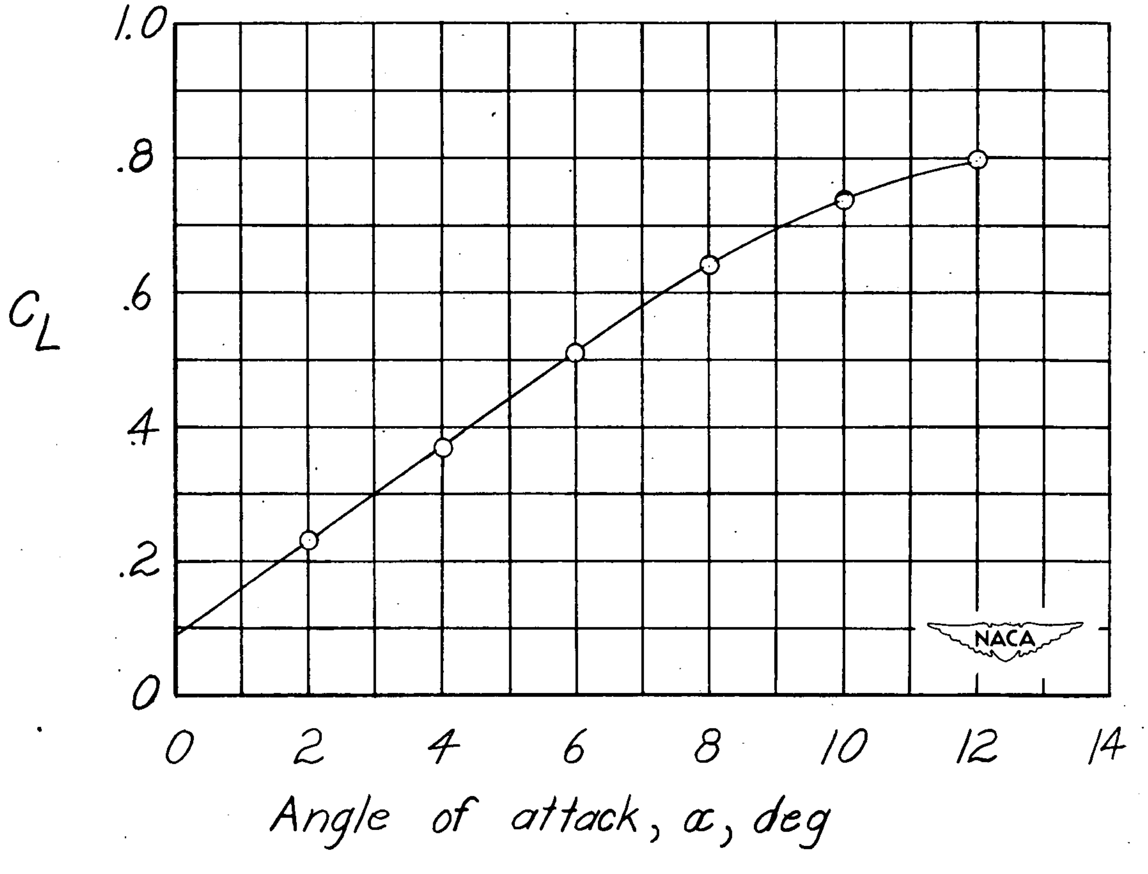
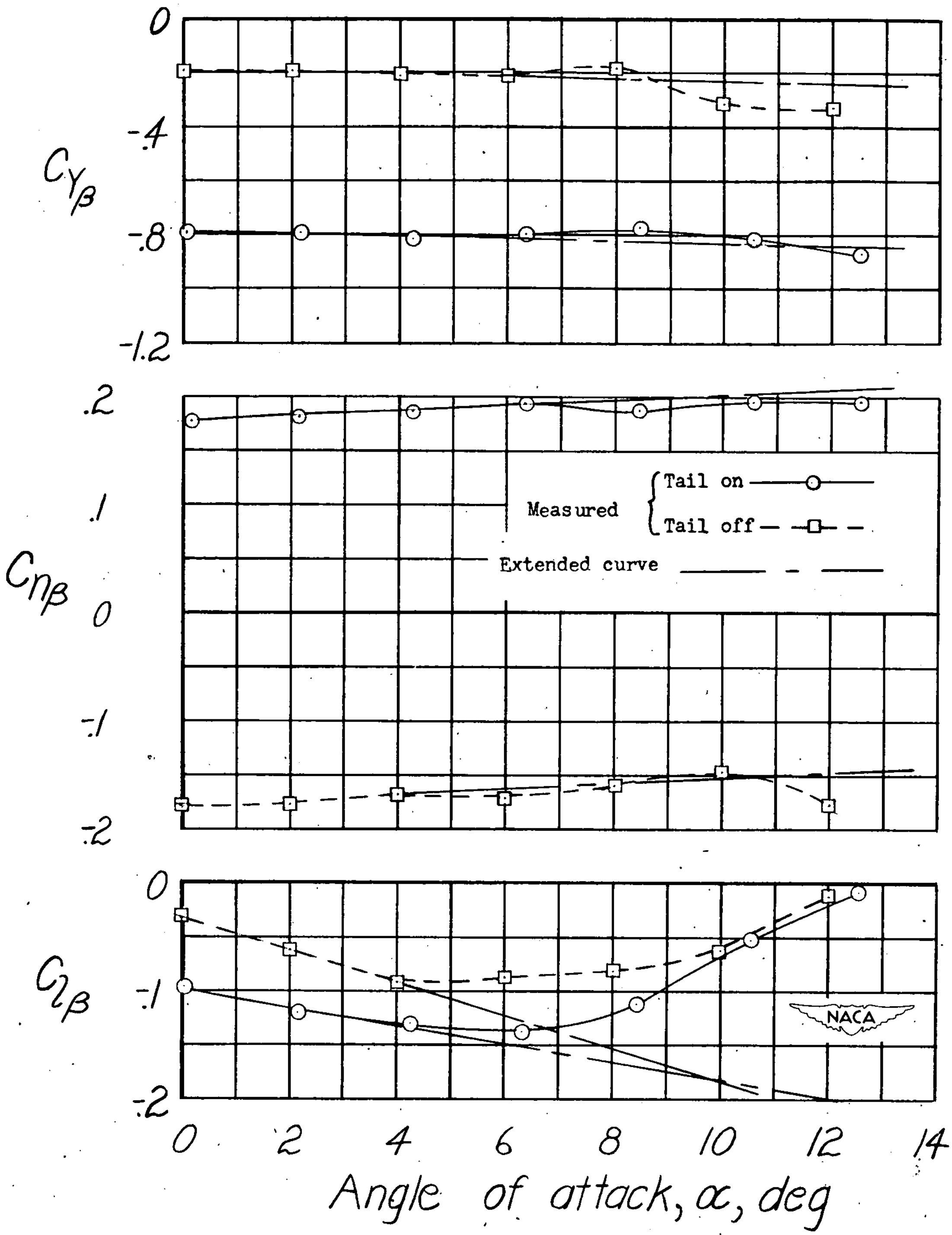
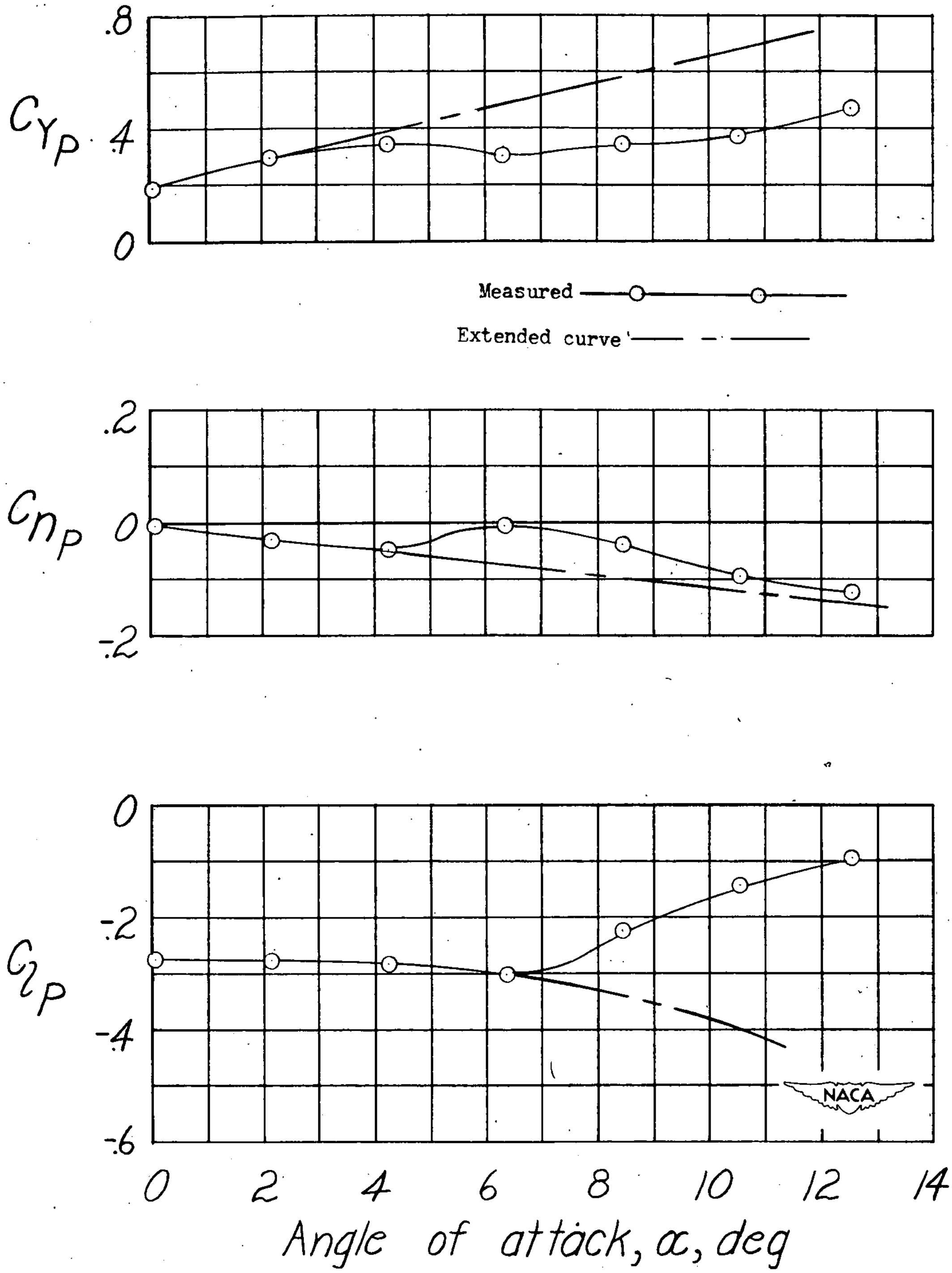


Figure 3.- Experimental variation of lift coefficient with angle of attack. M = 0.16.



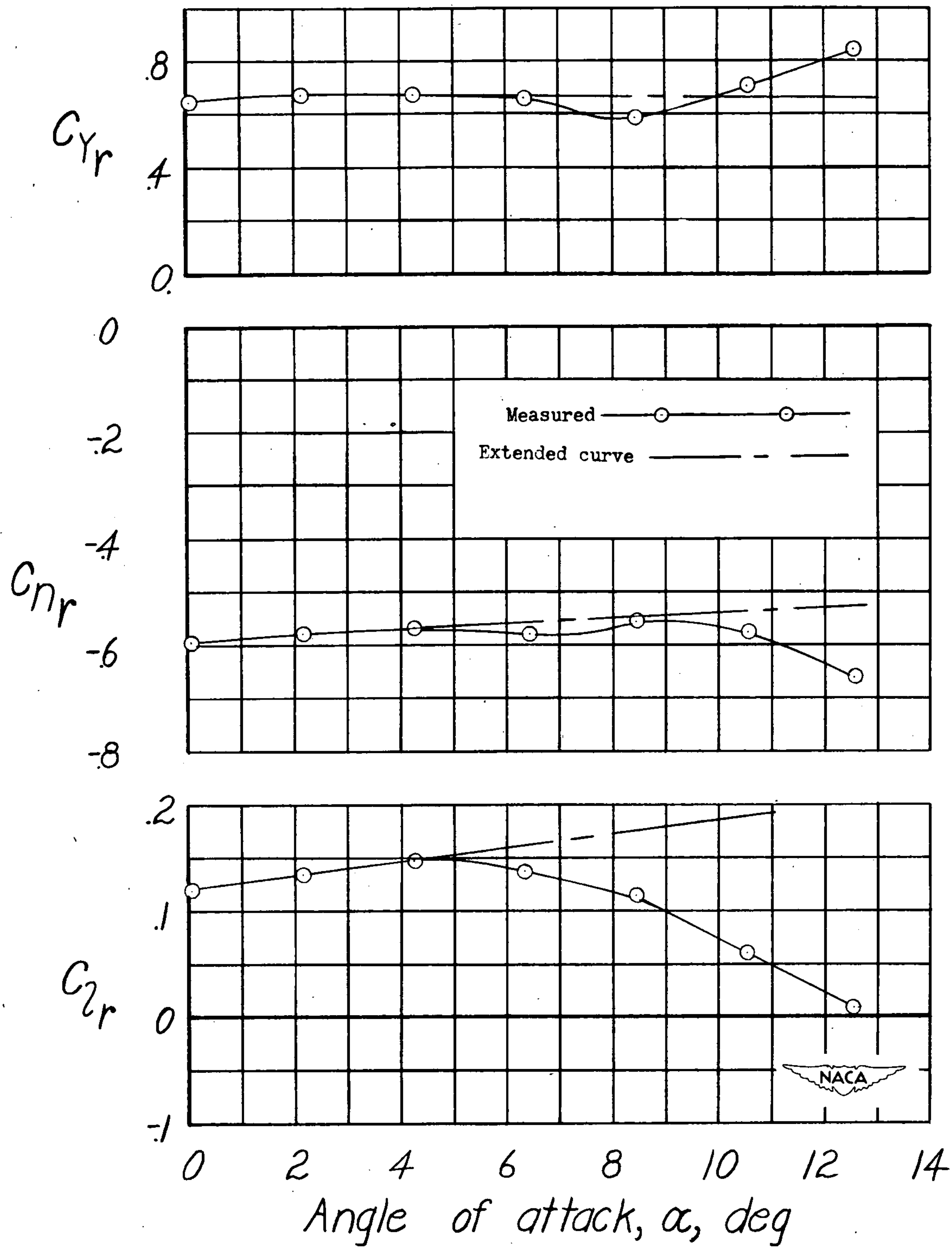
(a) Sideslip derivatives.

Figure 4.- Experimental variation of lateral-stability derivatives with angle of attack. M = 0.16.



(b) Rolling derivatives.

Figure 4.- Continued.



(c) Yawing derivatives.

Figure 4.- Concluded.

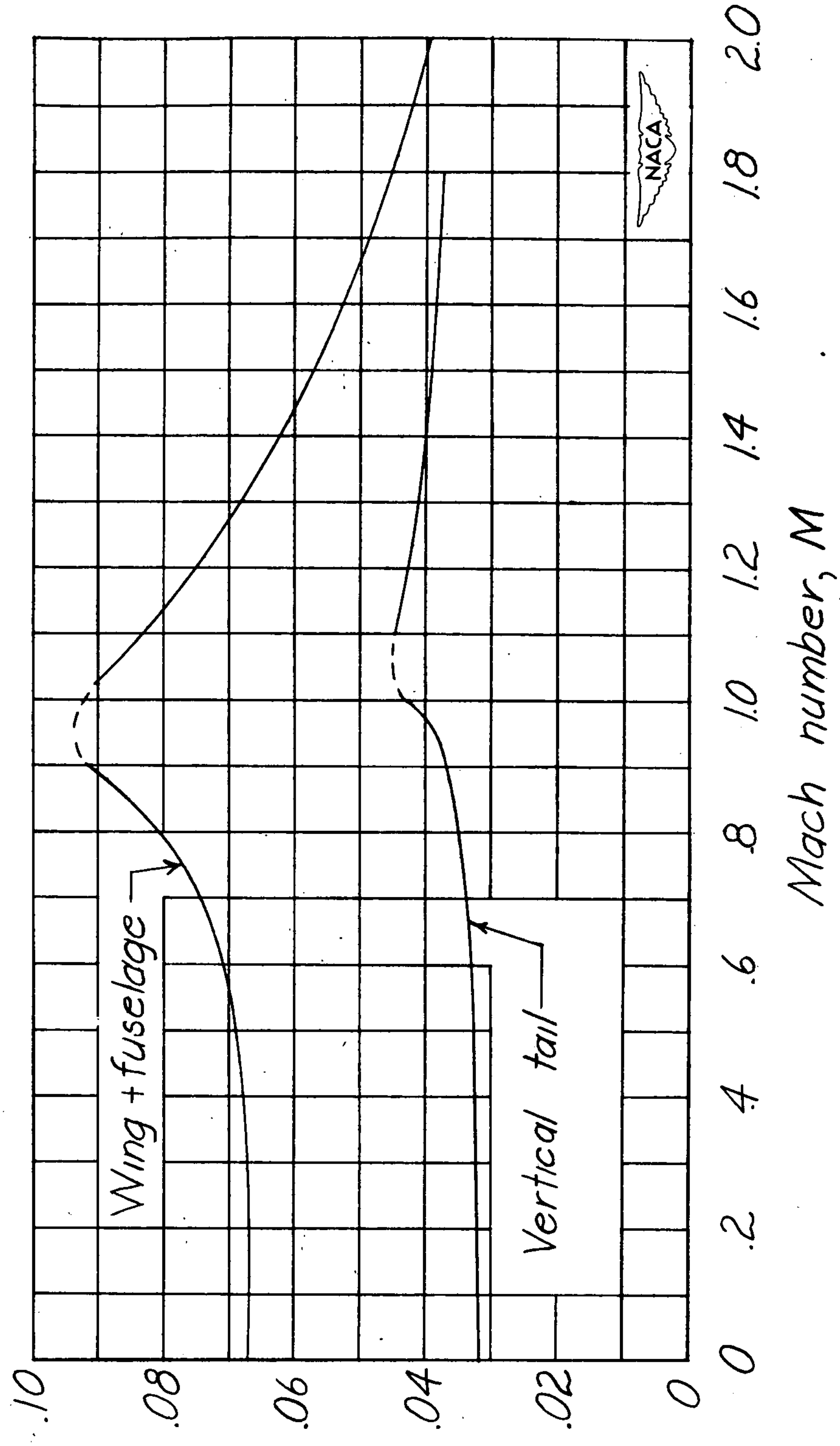
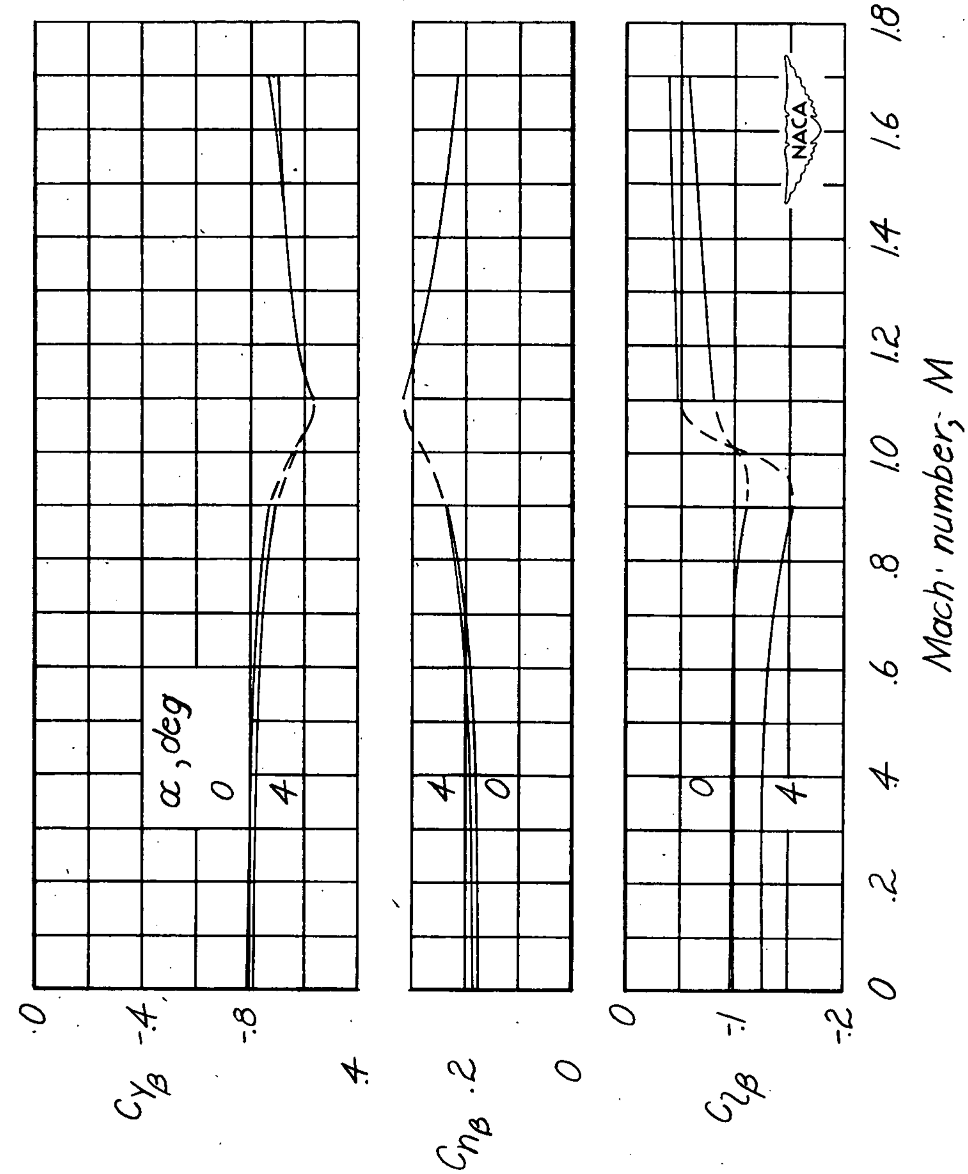
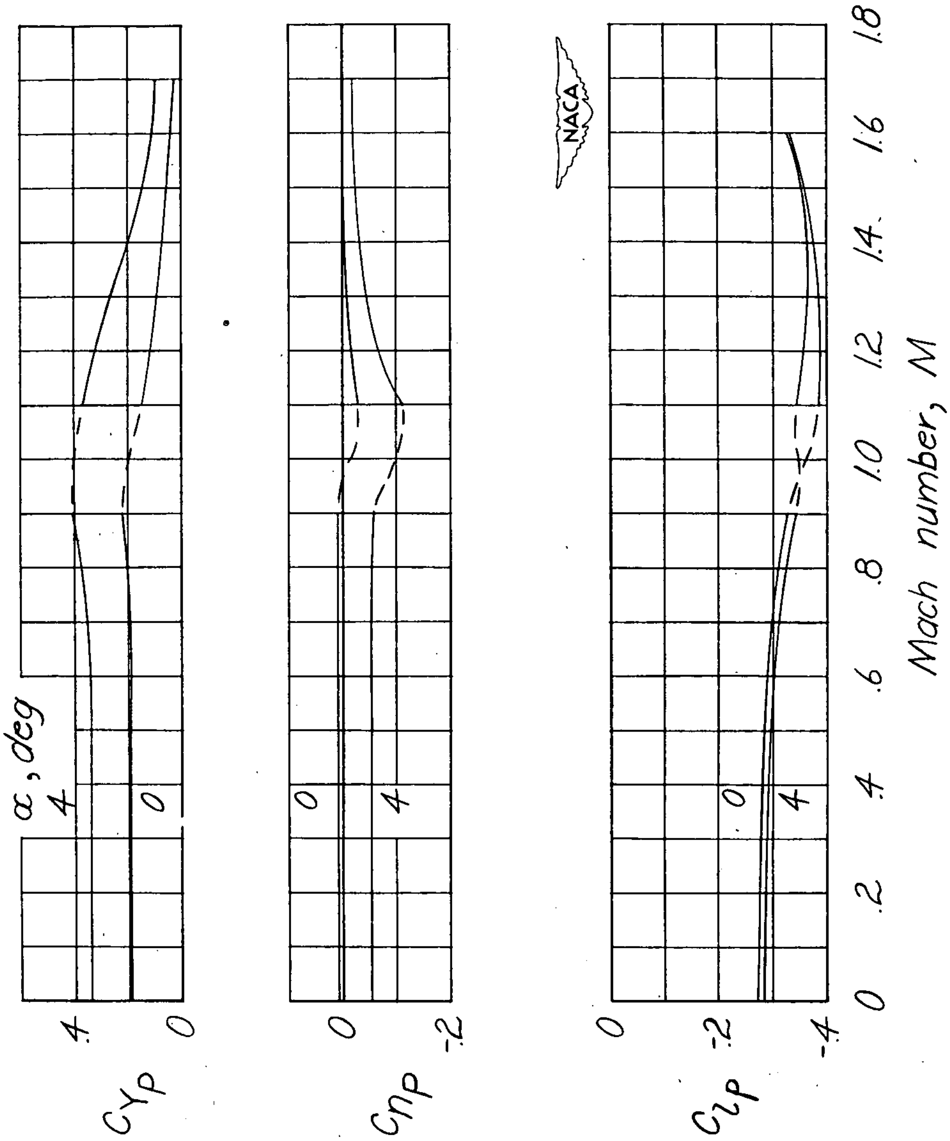


Figure 5.- Variation of wing-fuselage and vertical-tail-lift-curve slopes with Mach number. $\alpha = 0^{\circ}$.



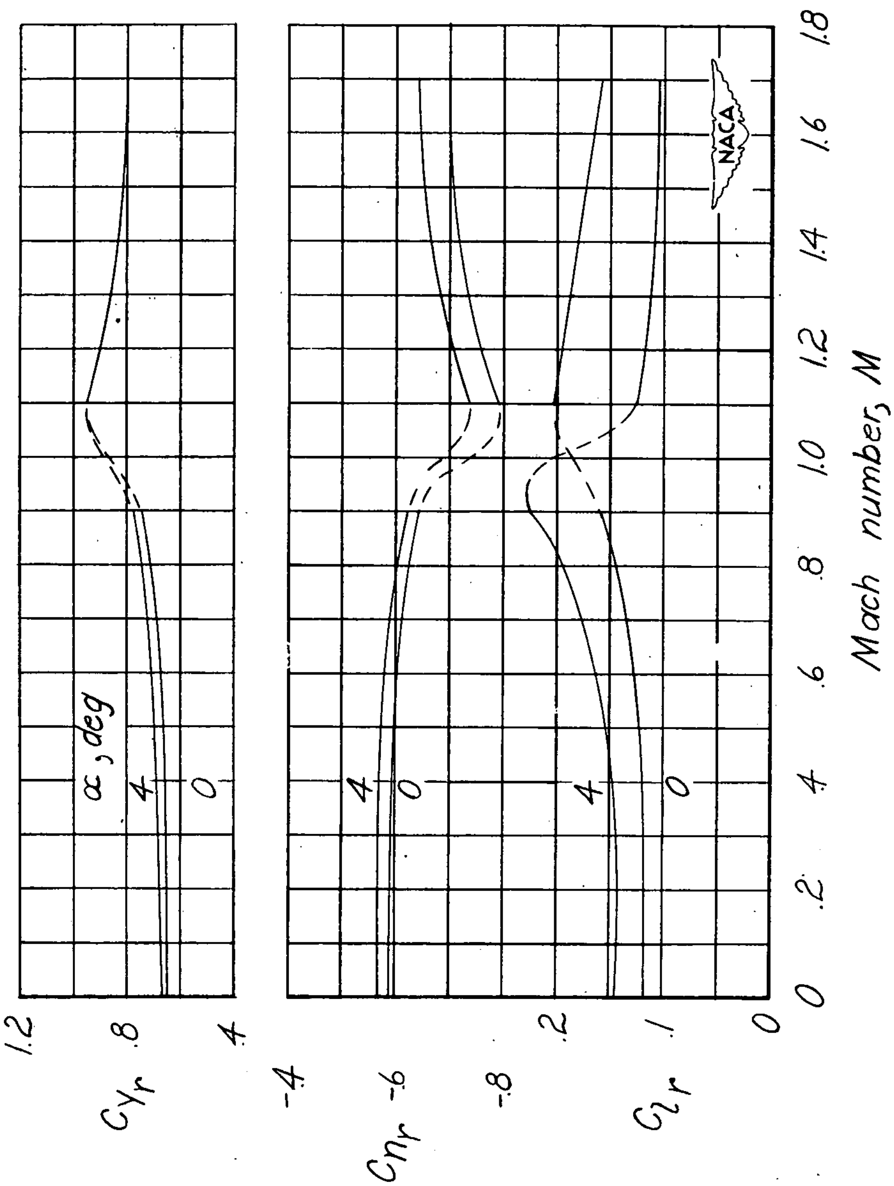
(a) Sideslip derivatives.

Figure 6.- Calculated variation of the lateral-stability derivatives of the Douglas D-558-II airplane with Mach number for two representative angles of attack.



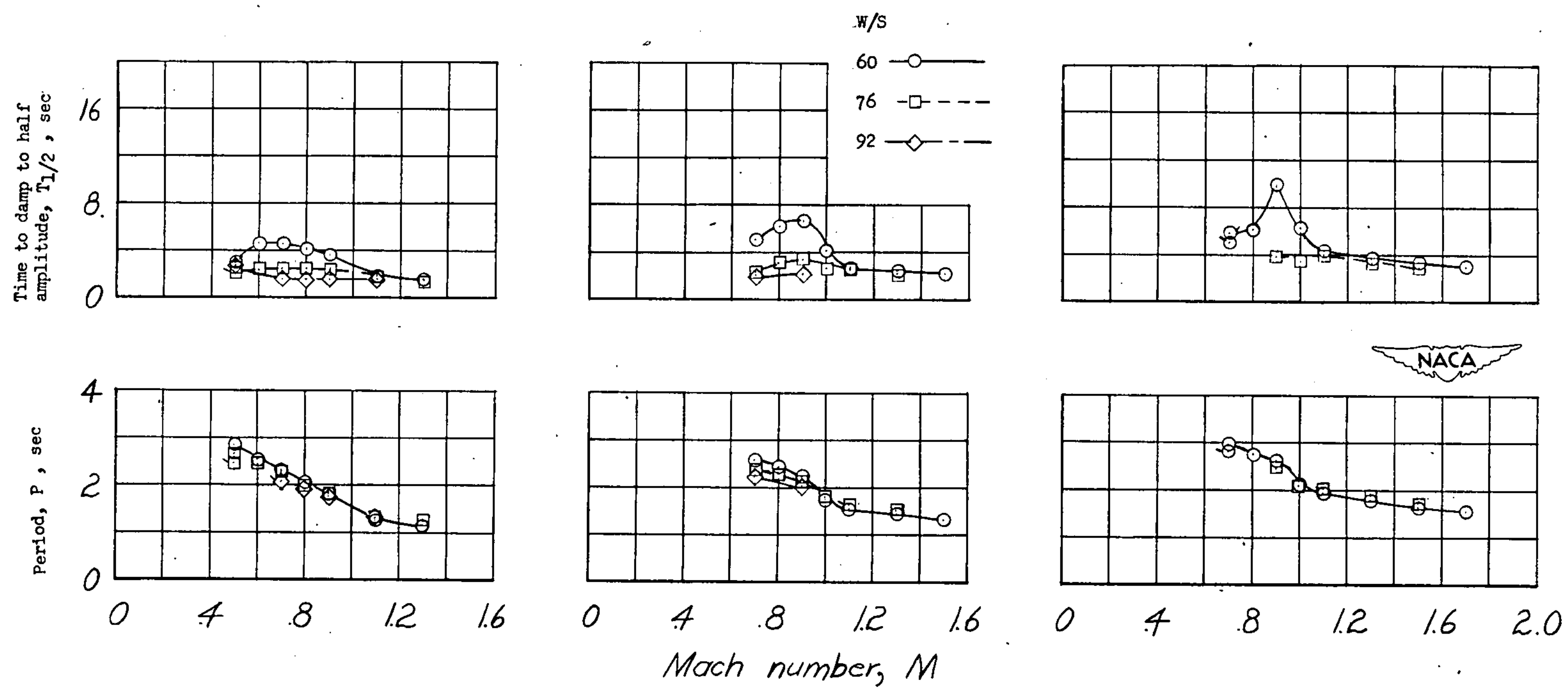
(b) Rolling derivatives.

Figure 6.- Continued.



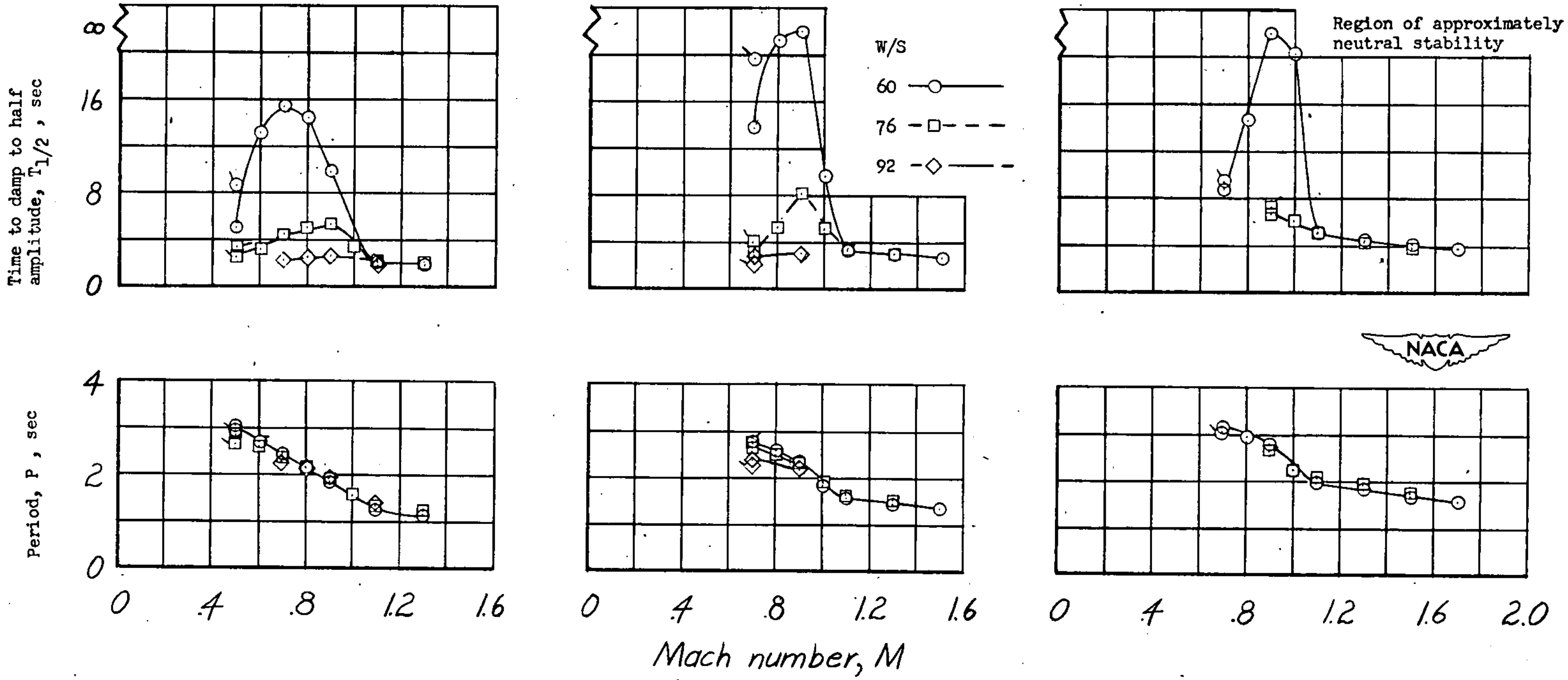
(c) Yawing derivatives.

Figure 6.- Concluded.



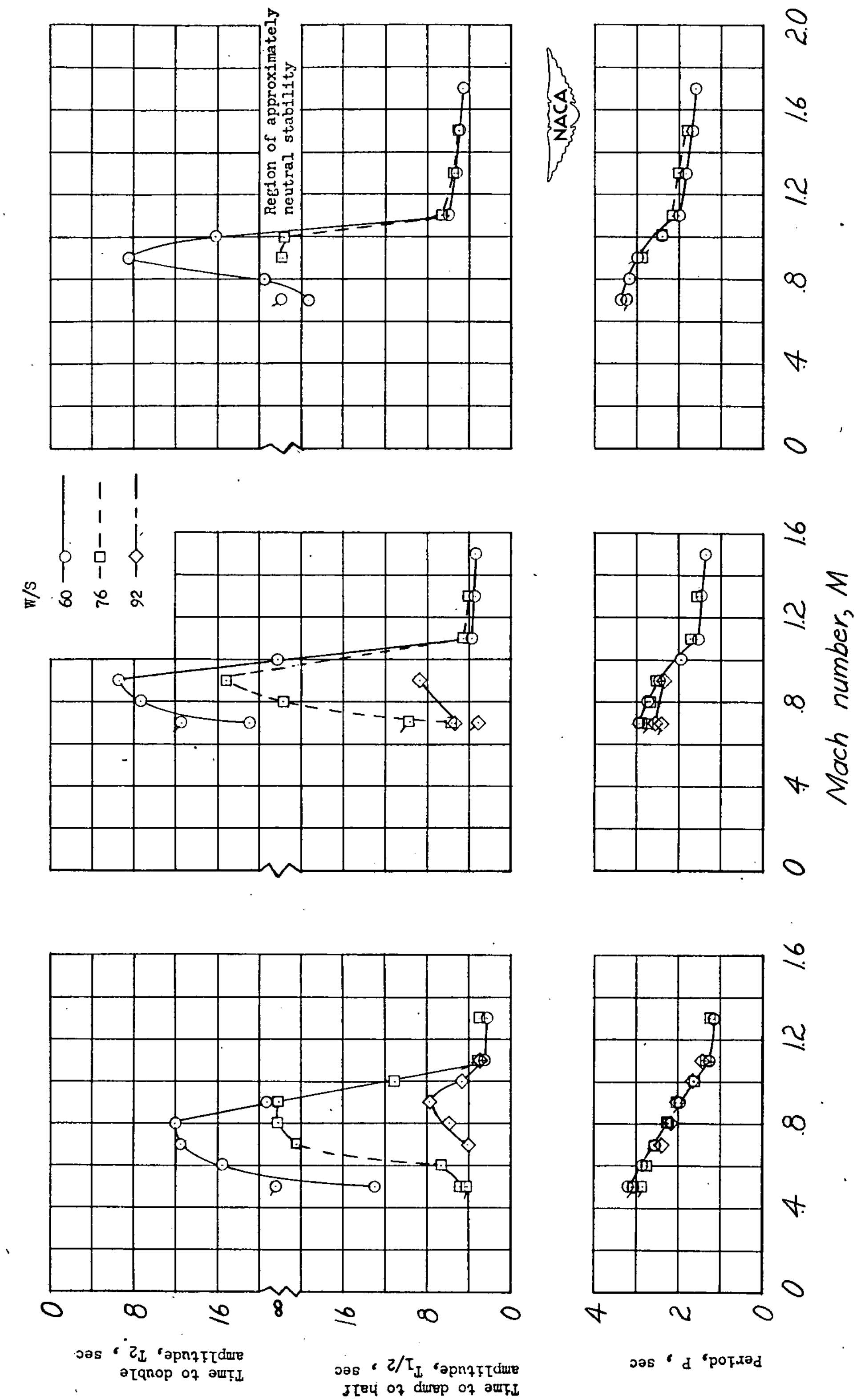
(a) H = 30,000 feet. (b) H = 40,000 feet. (c) H = 50,000 feet.

Figure 7.- Variation of the calculated period and rate of damping of the lateral oscillation of the Douglas D-558-II airplane with Mach number for several wing loadings and altitudes. $\epsilon = \epsilon_o - 2^\circ$. (Flagged points indicate use of data from extended curves.)



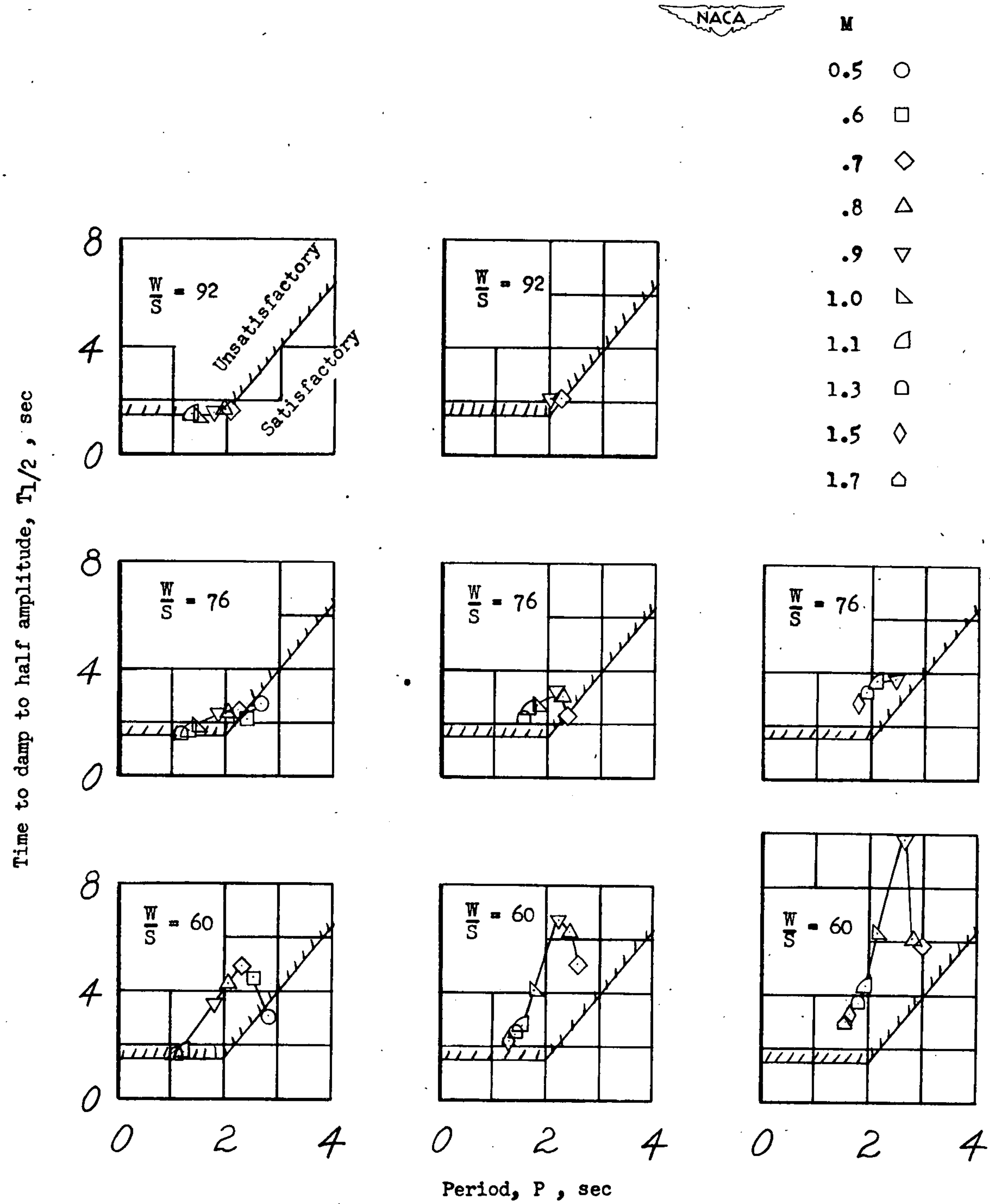
(a) H = 30,000 feet. (b) H = 40,000 feet. (c) H = 50,000 feet.

Figure 8.— Variation of the calculated period and rate of damping of the lateral oscillation of the Douglas D-558-II airplane with Mach number for several wing loadings and altitudes. $\varepsilon = \varepsilon_o$. (Flagged points indicate use of data from extended curves.)



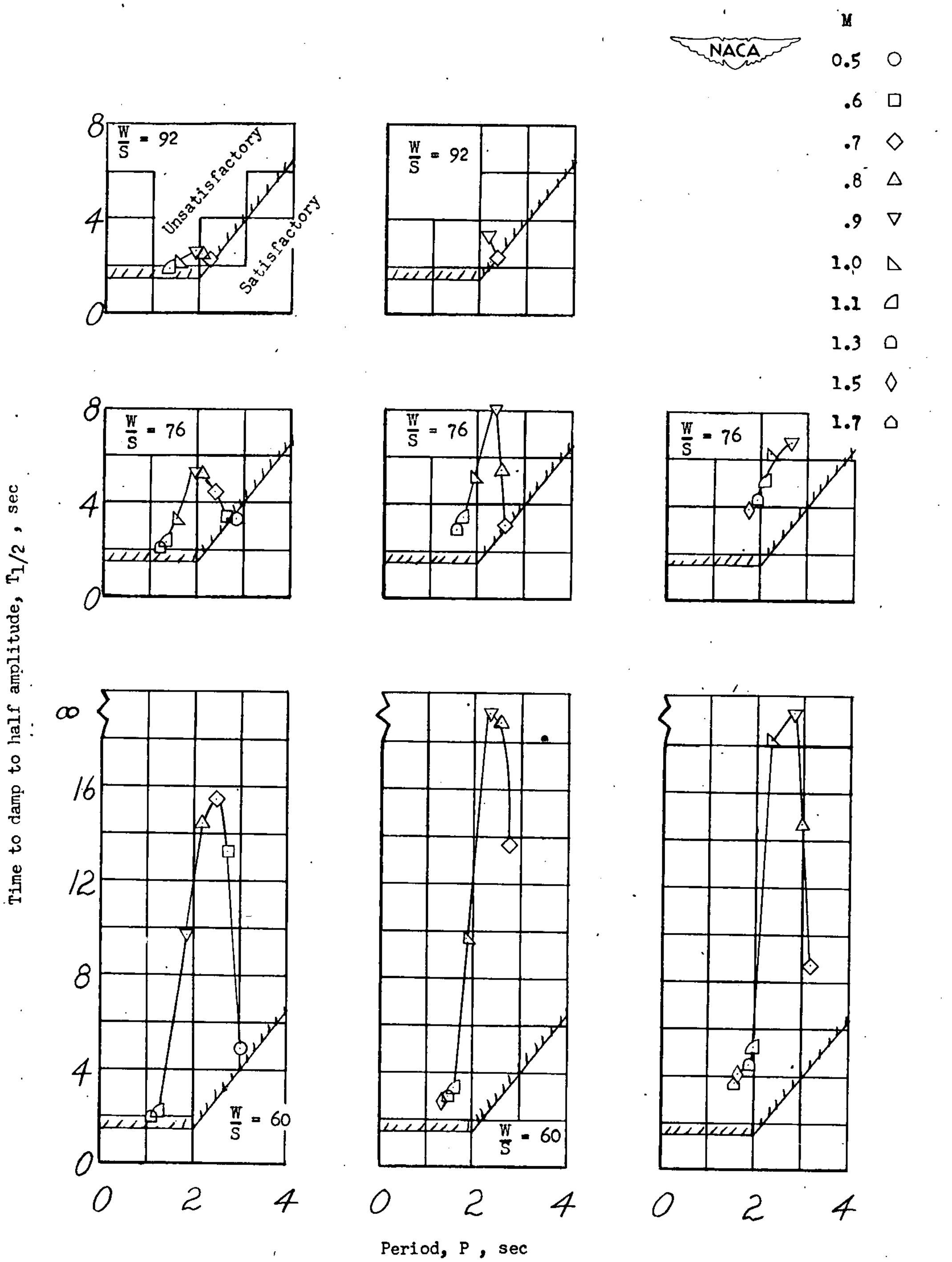
(a) H = 30,000 feet. (b) H = 40,000 feet. (c) H = 50,000 feet.

Figure 9.- Variation of the calculated period and rate of damping of the lateral oscillation of the Douglas D-558-II airplane with Mach number for several wing loadings and altitudes. $\epsilon = \epsilon_o + 2^o$. (Flagged points indicate use of data from extended curves.)



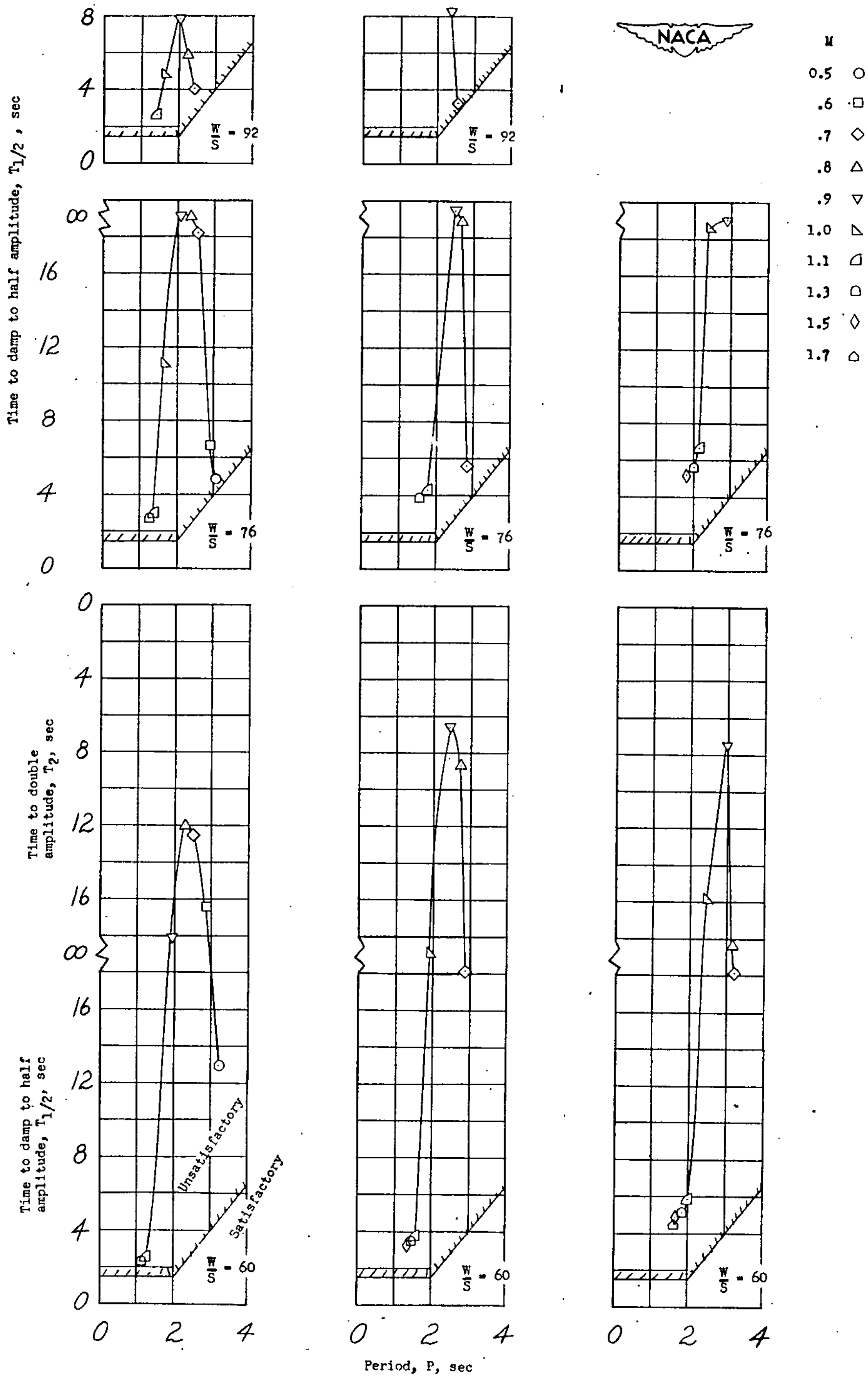
(a) H = 30,000 feet. (b) H = 40,000 feet. (c) H = 50,000 feet.

Figure 10.- Comparison of calculated damping characteristics of the Douglas D-558-II airplane with the Bureau of Aeronautics criterion for satisfactory damping. $\varepsilon = \varepsilon_o - 2^\circ$.



(a) H = 30,000 feet. (b) H = 40,000 feet. (c) H = 50,000 feet.

Figure 11.- Comparison of calculated damping characteristics of the Douglas D-558-II airplane with the Bureau of Aeronautics criterion for satisfactory damping. $\varepsilon = \varepsilon_o$.



(a) H = 30,000 feet. (b) H = 40,000 feet. (c) H = 50,000 feet.

Figure 12.- Comparison of calculated damping characteristics of the Douglas D-558-II airplane with the Bureau of Aeronautics criterion for satisfactory damping. $\varepsilon = \varepsilon_o + 2^{\circ}$.